DOCUMENT RESUME

ED 265 872 IR 051 415

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TITLE Information Technologies: What You See Is Not (Always) What You Get. Revised.
PUB DATE Jul 85
NOTE 35p.; An earlier version of this paper was presented at the Annual Meeting of the American Educational Research Association (Chicago, IL, March 31-April 4, 1985). Support provided by the John and Mary L. Markle Foundation.
PUB TYPE Information Analyses (070) -- Viewpoints (120) -- Speeches/Conference Papers (150)

EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS *Cognitive Mapping; Computer Assisted Instruction; Computers; *Epistemology; *Information Science; *Intellectual Development; *Learning Processes; Perceptual Development; Position Papers; Psychological Studies

ABSTRACT

This paper examines the gap between the learning potentials that computers provide and the actual impact of computer use on learning and development. It is argued that the computer's unique potential is derived in part from four basic attributes: information, symbol systems, user activities, and relations with the user. It is hypothesized that these attributes may affect four corresponding cognitions: knowledge structures, internal modes of representation, mental operations, and attitudes and perceptions. These effects may be obtained through "low road" learning (practice-intensive, leading to near automatic responses), or through "high road" learning (thinking-intensive, i.e., nonautomatic operations are mindfully employed). High road learning is seen as the more feasible and promising means to facilitate conceptual learning with computers. The extent to which high road learning occurs depends on the learners' volitional mindfulness, which in turn is partly determined by the materials encountered and by personal, perceptual, and attitudinal factors. It is argued that the opportunity for mapping the computer's attributes on corresponding cognitions often does not take place because learners do not become mindful on their own. The partner-like relationship which the computer can establish with the students can promote mindfulness, but it is the student's choice as to how mindful they will be while interacting with the computer. (Author/THC)

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INFORMATION TECHNOLOGIES:

WHAT YOU SEE IS NOT (ALWAYS) WHAT YOU GET

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may 1985
REVISED JULY 1985

Running Head: Computers, learning, development, and mindfulness.

An earlier version of this paper was presented at the 1985 Annual Meeting of the American Educational Research Association. The author wishes to acknowledge the support of the John and Mary L. Markle Foundation.
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ABSTRACT

The purpose of this paper is to draw attention to the gap between the learning potentials afforded by computers and the actual learning from them. Computer's unique potentials emenate from the kinds and varieties of four basic attributes - information, symbol systems, user activities, and relations with user - which it offers. These attributes may affect four corresponding congitions - knowledge structures, internal modes of representation, mental operations, and attitudes and perceptions, respectively, by either activating, supplanting or short-circuiting them. Such effects could be obtained through "low road" learning which is practice intensive, leading to near automatic responses, or through "high road" learning, which is thinking-intensive: nonautomatic operations are mindfully employed. The high road is seen as the more feasible and promising road to conceptual learning of the kind computers can facilitate. However, the extent to which high road learning actually occurs greatly depends on learners' volitional mindfulness, itself partly determined by the nature of the materials encountered and partly by personological, perceptual and attitudinal factors. It is argued that the opportunity for mapping computer's attributes on their corresponding cognitions, although often available, does not always take place as learners do not always become mindful on their own. Computer's promise does not lie in its attributes alone, unique and powerful as they

may be, but with how mindfully learners come to handle them. One important computer attribute - the partner-like relationships with learner it permits, and a number of instructional practices are discussed as possible means to promote and sustain learners' mindfulness.

Information Technologies: What You See Is Not (Always) What You Get[1]

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Information technologies often arrive on the educational horizon in a great crescendo, promising to save education from its malaise, thus demanding central stage. Some technologies slip quitely out through the rear door, never to be heard of again; others stay behind becoming content to play a relatively minor role; and still others are repeatedly reborn - broadcast TV turning into VTR's which in turn give way to videodisks. But computers - the one in many centuries invention - for their power, low price, and versatility, are apparently likely to dominate the educational arena for a long time to come (e.g., Kleiman, 1984). Their potential for education seems to be vast indeed.

Yet given the less than glorious history of technologies past and present (Clark & Salomon, 1985), one needs to become aware of the often overlooked gap between the opportunities <u>afforded</u> by the new information technologies and their <u>actual</u> impact on learning and development (e.g., Linn, 1985). In this paper I argue that whereas the computer entails many, and often unique and individually tailored learning opportunities, their realization greatly depends on learners' choice as to how mindfully to handle them. Perhaps paradoxically, the more of a

unique opportunity there is for learning, in part a result of the control learners have over the learning process, the more do the learning outcomes depend on learners' voluntary engagement in learning.

Two basic issues are involved here: the nature of the learning opportunities that computers can provide and the conditions under which learners actually take these opportunities. Concerning the learning opportunities, it can be said that because computers are extensions of our mental capacities, their functions correspond in principle to cognitive ones and can map upon them in relatively unique ways. From playing an ecological simulation game in which information is presented in a variety of symbolic forms, one may acquire knowledge about the multivariate nature of the ecology, acquire new modes of internal representation, and improve the mastery of metacognitive skills (e.g. Dickson, 1985).

Relatedly, computers, more than any other means of instructional communication and activity, can be differentially adapted to learners' cognitive capacities, prior knowledge, learning styles and desires (e.g. Globerson, this issue). Thus, computers' informational, symbolic and operational attributes - when capitalized upon - can map upon their cognitive counterparts in ways that are individually tailored to be within a learner's cognitive reach. Moreover, this capacity for flexible adaptation is enhanced by the control over the learning process that computers allow the learner. In this way technology may

increase the chance that the provided learning opportunities can be taken in actuality.

All this concerns what learning opportunities computers can potentially offer. Enters the question of what students do in actuality with these opportunities: Do they indeed generate relevant hypotheses, plan ahead, compare alternatives, evaluate simulation outcomes, thoughtfully examine feedback, and think analytically, when such are afforded and called for?

Not many opportunities for "deeper" learning seem to be taken advantage of just because they are there (e.g., Corno & Mandinach, 1983; Zelman, 1985). Even when information technologies afford unique learning opportunities and can adapt to learners' capacities and knowledge structures, the ultimate learning outcomes much depend on learners' actual mindfulness in learning. Learners' choice of midfulness depends to no small extent on their expectations, perceptions, attitudes, and goals. Thus, this mindfulness in learning is in no small measure a volitional matter, the importance of which increases the more control over the learning process students are given.

In what follows I will first discuss computers' potentials: the ways in which the components of technology can differentially map upon cognitions. I will then try to show the role played by students' volitional mindfulnes in realizing these potential opportunities. Finally I turn to the reciprocal interaction between mindfulness and instructional features.

The potential: mapping computers' attributes onto cognition

All instructional means, from face to face conversation to the word processor, entail four basic components: Information - either provided or learner-generated; symbol systems in which the information is cast; particular activities that the instructional means afford or demand; and the kinds of student-technology relations that become possible. By information I mean conceptual and factual contents; by symbol systems I mean the representational codes, or "languages" used (pictures, musical score, words, dynamic three dimensional graphs); and by activities I mean such things as viewing, debugging, listening, choosing an answer, composing a string of musical notes, writing a paragraph, programming, or manipulating a variable. Finally, by relations I mean the difference between the computer as authoritative instructor, tutor, intelligent partner, or as a tool controlled by the learner.

These components, or attributes, apply of course to all instructional means. But computers differ from more traditional means such as television and face to face communication in the kinds of information that they can handle and the versatility of symbol systems they can use. The most profound differences lie, however, in the interactive capacities of computers as manifested in the range of activities they afford (and replace), and in the kinds of relationships they allow.

Think of the information available when one is shown how an object "behaves" in space when different forces are applied to it, or think of computers' capability to represent music as colored shapes varying in size, width and duration. Similarly, consider the kinds of mental operations possibly tapped during programming in Logo, or when multivariate simulations are manipulated. Finally, think of the kinds of relations between user and computer that can evolve when a student writes a story on a "smart" writing tutor, the computer continues it for a while, then the student takes over again, and so on, until the story is done. In each of these examples, a relatively unique feature - content, symbolic form, activity or relationship - is capitalized upon with the hope for a similarly unique cognitive effect.

If information technologies are extensions of the mind, and if "intelligence is skill in a medium" (Bruner,1964; Olson, 1976; 1985), then reciprocal relations between mind and culturally evolved technologies must be implied (Gardner, 1985). It follows then that information technologies and mind possibly entail corresponding, or analoguous components and functions (see also Cole & Griffin, 1983; Salomon, 1979; Vygotzky, 1978). In this light, it can be argued that the four components of technology (information, symbol systems, activities, and relations) can map upon four corresponding components in learners' cognitions. These are <u>knowledge, internal modes of information representation, mental operations</u>, and <u>perceptions and attitudes</u>, respectively.

Information is always coded in some symbol system and demands some kind of mental activity on the receiver's part. Thus, it would follow that information always addresses all four cognitive components simultaneously. From reading a map you can acquire information about the terrain, you can learn to represent geographical terrains to yourself in a particular spatio-imagery code, you can acquire skill in map reading, and you can learn how to relate to maps and what to expect from them.

However, as recent developments in the cognitive science suggest, knowledge is usually domain-specific and organized in coherent schemata the content and structure of which is affected primarily by the informational content of newly encountered materials (e.g., Glaser, 1984); information maps upon knowledge structures. Communicational symbol systems, as differentiated from the content, appear to affect internal modes of representation (Dickson, 1985; Salomon, 1979); one may learn to think in terms of the cultural symbol systems encountered through media and technology. Similarly, activities - such as exercising control or writing, as distinguished from what is controlled or written - affect mastery of relevant mental operations (Benware & Deci, 1984; Olson, 1976). The activity of revising an essay on a word processor may facilitate the skill in writing as a problem solving process (e.g., Pea & Kurland, 1984b). Finally, relationships with the technology appear to affect such perceptions and attitudes as academic self-confidence (Griswold, 1984) and computer anxiety (Cambre & Cook, 1985). It follows,

then, that the four components of information technology address primarily their corresponding cognitions, and secondarily also the other components.

The more unique the components of information technology employed, the greater the chance of uniquely affecting corresponding cognitive functions. For example, an AI-based writing tutor will soon be capable of explicitly feeding back to a writer the emerging structure of his or her essay. Such information, which was not often available to students until now, is likely to affect numerous kinds of cognition, but mainly - the students' knowledge of essay or story structure (e.g., Levin, Boruta, & Vasconellos, 1983). The computer's unique ability to provide translations among different symbolic modes of representation and to allow students to control such juxtapositions may increase competence in shifting among cognitive representational systems and cultivate metacognitive skill (Dickson, 1985). Similarly, programming-related activities may, quite uniquely, call upon such mental operations as procedural logic and top-down planning thus develop them in ways not easily attained otherwise (Pea & Kurland, 1984a).

The four components of information technologies, alone or in interaction with each other, affect corresponding cognitions in either one of three major ways: They can (a) activate prior knowledge structures, internal reperesentations, and particular operations; (b) they can explicitly model or supplant such

cognitions; or (c) they can "short circuit" them, that is - handle them for the learner.

The idea of activation of cognitions is at the route of Wittrock's model of instruction as a process of generative learning (1978), where he assumes that "instruction involves stimulating the learners' information-processing strategies, aptitudes, and stores of relevant specific memories in relation to the information to be learned" (p. 26). Indeed, when it is argued, for example, that programming requires exact procedural thinking in a top-down fashion, that "writing promotes thinking", or that simulations afford the opportunity to generate hypotheses and test them, it is assumed that particular units of information, symbolic modes of presentation, or activities activate corresponding congnitions. The activation of relevat cognitions is seen as the sine qua non of learning and of the cultivation of skill. This, to a large extent, is one of the main bases on which the teaching of programming rests: programming is assumed to activate logical processes thereby cultivating them.

The second mechanism for mapping computer's components on their cognitive counterparts is modelling. Information, symbolic modes, or activities to be learned are explicitly provided and shown, the expectation being that they will be internalized to be used as mental models (Minsky, 1970), or mental operations (Salomon, 1979). Moreover, it is often also assumed on the basis of a Piagetian view, that the overt activities learners are performing will themselves be internalized to become mental

operations (e.g. Papert, 1980). Thus, some of the activities involved in programming (e.g. debugging), or in the manipulation of simulated variables may, so to speak, "go underground" and function as procedural knowledge.

The third mechanism - "short circuiting" - aids in affecting cognition by facilitating the selection of those cognitions deemed most relevant to the learning process. One of the great advantages of information technology is in its capability to "take over" processes and activities which are considered unnecessary, or even causing interference. These are carried out covertly by the technology (say, computation or charting of data) relieving the learner from their burden and allowing him or her to concentrate on other processes. Such short-circuiting is unrestricted by the limitations of human processing capabilities, thus making, say, the problem solving activity a joint venture of learner and technology: the learner is the problem solver, the computer - the tool that carries the process out.

A process short circuited is, of course, not a candidate for acquisition. But its short circuiting saves unnecessary mental effort and can redirect effort to where it is deemed more important. Indeed, computers can present information in uniquely structured ways that can save learners the need to organize the information; it becomes more available for retrieval or for additional reorganization.

An example of the above can be found in a program, developed at the Tel Aviv University Lab for the Study of Computer

Applications in Education. This program was designed to teach how ecological variables interact. Little knowledge is presented. Learners have to figure out the optimal combination of variables to keep a population of fish stable, or to increase its size for economic purposes. They manipulate such variables as average litter size, age of maturity of the species involved, amount of food provided, and the like. This they do by selecting variables from a given menu, plugging in numerical values, and observing the resultant process. Results and data are provided by means of a dynamic pictorial depiction of of the process in a lake, a dynamic graph, and a numerical spread sheet, among which learners can freely move. These data representations permit students to test hypotheses they generate while trying to solve particular ecological and economic tasks.

This program assumes that the knowledge about the interaction of variables in the ecology will be acquired by creating experiential knowledge. The events on the screen come to be a real ecology in which changes can be affected and experienced. Thus the program assumes that learners will generate hypotheses that are actually tested in a microworld that shows results immediately. But this program, whether intended or not, also models, or supplants the way in which a dynamic process can be represented in three alternative symbolic forms, possibly allowing these to be internalized as future tools of mental representation.

Additionally, the program assumes that the activities the learners engage in function in two capacities. First, they are expected to facilitate knowledge acquisition, possibly through the choices learners encounter and the information they have to conjure up and process in the service of making a decision (Olson, 1976). Second, it is expected that the active manipulation of variables, the shifting from one symbolic representation to another, and the generation and testing of hypotheses will affect skill mastery. For example, skill in mentally manipulating several variables simultaneously may be cultivated by strengthening operations the program activates, and through the internalization of the activities themselves. Finally, the way the program is structured implies the expectation that the partnership evolving between program and user will affect the latter's attitudes toward and perceptions of ecology and of self as part of it.

Herein may lie the important functional differences among information technologies. The more a technology can be designed to activate, model or short circuit cognitions hitherto untapped by other means, the greater its opportunity for fostering unique learning effects, making a difference in learning and development. But such opportunities, as I will try to show below, do not become realized on their own.

Cognitive demands

The components of technology, as I have argued, can potentially map upon their cognitive counterparts by either activating, modelling or short circuiting them. But there is a difference between the incidental activation of some planning operations during a child's attempts to get a turtle to draw a hexagon, and when it is done deliberately in the service of testing hypotheses about the number of degrees in closed shapes. Although the former may be the more desirable way (Papert, 1980; Lawler & Papert, 1985), it is, unfortunately, not always practical, nor too effective (Leron, 1985; Salomon, 1984a).

The mapping of technology's components on their corresponding cognitions can take two routes. There can be "low road" activation or modelling of cognitions (Perkins & Salomon, in press), whereby learning is a matter of much and varied practice such that overlearning and its correlate of near automaticity are attained : cognitions come to be effortless and stimulus-controlled (Schneider & Fiske, 1984), and can be carried out with little mindfulness (Langer & Imber, 1979). This is possibly the case with typical CAI programms and with children's repeated play with some computer games that afford the incidental employment of inductive logic (Greenfield, 1984). Such overlearning, often a correlate of playful activity, can result in intuitive, informal or tacit, rather than in formal knowledge. Although such learning may be an important base for further

learning, it also tends to develop rigid habits which are mindlessly applied (Langer, in preparation). As the knowleidge is mainly intuitive, it is not as easily modifiable as is more formal knowledge (e.g., Olson & Bialystock, 1983).

Alternatively, there can be activation and modelling that follow the "high road" of learning (Perkins & Salomon, in press), whereby learning is a matter of deliberate, often efforful, and volitional application of non-automatic processes. This is the case when one seeks out a main idea, generalizes, abstracts, generates inferences, and tries to discover "powerful ideas". Such deliberate midfulness facilitates memory (Kintsch, 1977), and inferential learning (Salomon & Leigh, 1984), and is greatly facilitated by self-regulatory metacognitions (Glaser, 1984). It is more likely to be the route taken when personally important problems are to be solved, when one is motivated to discover a principle, to formulate a generalizable rule, or to share the knowledge with somebody else.

The difference between the two routes can explain why, for example, impressive learning and transfer results from programming are found in some cases (e.g., Clements & Gullo, 1984) and not in others (e.g., Pea & Kurland, 1984a). Learning to programm would have to follow the low road, the high road, or a combination of the two. But no provisions for low road learning with the extensive overlearning it requires are usually made. The high road could not be a much better candidate either <u>unless</u> students are made to expend the needed effort for mindful

decontextualization of such concepts as recursion. or such skills as the ones involved in planning. Indeed, this may have been the case in the study by Clements and Gullo (1984) where one instructor was assigned to every two or three learners and worked with them through the Logo problems encountered. As Leron (1985) and others have observed, Logo could teach "powerful ideas", perhaps even cultivate generalizable skill, only under well structured instructional conditions; children just do not become very mindful spontaneously, regardless of the potential for mapping Logo's ideas and activities on their cognitions.

For practical and psychological reasons, it appears that the high road is often the more feasible one for the kind of formal learning that computers can provide. Low road learning requires much repeated practice and serves better the cultivation of intuitive knowledge, attitudes, perceptions, and habits than higher order concepts, inferences, hypothesis testing and abstractions (Perkins & Salomon, in press). The mapping of computers' informational, symbolic and activity components thus greatly depends on the extent to which the high road of learning is taken.

Opportunities afforded and opportunities taken

But is the high road of learning always taken <u>in actuality</u>? It would seem that when unique and realizable opportunities are provided that cognitions are affected, as expected. For example, one might expect that when learners can shift among three

symbolic modes representing the same information, that they will indeed try to interrelate them; or that when a word processor short circuits many menial activities of writing and editing, that top-down planning operations of the essay will become activated. But learners may <u>appear</u> to do the right things, go through the correct steps and motions, and provide the required responses. And yet, the desired high road learning is not attained. As Chanowitz and Langer (1980) have observed, "The apparently structured environment <u>suggests</u> certain modes of humanly minded engagement, but it does not <u>dictate</u> that mode" (p.102).

Consider, by way of example, the case of control in computer-student interactions. Control is the experience of contingency between actions and outcomes. This experience correlates with achievement behavior, with competent performance in school, with curiosity, exploration, and intrinsic motivation (see review in E. A. Skinner, 1985; Lepper, 1985). However, according to Chanowitz and Langer (1980), control <u>can be attained</u> either mindlessly or mindfully. These two modes of control are similar in appearance but different in experience and outcome.

Imagine a student composing music at the computer. After each couple of minutes, the student listens to her composition, revises it, tries to improve it, and continues with the next segment. It can be said that the student controls the developing score: She faces certain choice points where decisions need to be made on the basis of some information. She evaluates the

alternatives and makes a choice, which she subsequently reevaluates.

What choice points has she actually dealt with? What alternatives have been considered? Have choices been made mindfully on the basis of newly encountered alternatives? Have new distinctions been made and has novel information been considered? Was the student guided by a desire to achieve something new? Or have the choices been made more mindlessly by trial and error, with no clear plan in mind, and no new information considered? Was the purpose to reconstruct something already acheived in the past?

Control is exhibited whether the composing is done in one way or nother as ends are contingent on the student's actions. But in one case the composing student produces changes in the environment by mechanically employing well mastered large chunks of integrated behaviors based on already made distinctions. In the other case the student exercises control by making new discoveries and distinctions, thus experiencing a change in herself, not only in the environment. Although in both cases the interaction appears to go through the same motions, the subjective experiences accompanying the activity are vastly different, and so are their learning consequences. The mapping of technology's components on learners' cognitions that result in any lasting changes in knowledge, cognitive representation, or skill mastery, are more likely to result when mindful control is

exercised than by the more mindless, haphazard control. Consider a few research findings.

Salomon (1984b) and Salomon and Leigh (1984) found that children, particularly the more intelligent ones, view television as a relatively "easy" medium requiring them to spend little mental effort in processing its content. True to their general initial perceptions and attributions, these children fail to mobilize their available abilities, relying on the processing yield of their automatic processes while watching even a cognitively demanding television program. Little wonder that they show less inferential learning than their less intelligent peers who are more mindfully engaged in processing.

Such findings are not unique to TV. Leron (1985) observed that many Logo learners tend to engage in a "hacking" kind of programming, not very conducive to the acqusition of "powerful ideas". This style, as he describes it, is characterized by trial and error with little reflection and understanding of the deeper ideas behind Logo, even where bright twelve year olders are involved. Such observations are very much in line with those of Pea and Kurland (1984a), Zelman (1985) and Linn (1985) concerning the poor results of learning to program. It appears that much low road learning takes place where high road learning should be expected. For what is presented and potentially evoked, even when adaptation to individual differences is possible, is not necessarily encountered, picked up, experienced and applied unless focussed mindfulness becomes involved. Mindfulness, then,

appears to determine the potential impact of learning-oriented interactions with the computer. What determines mindfulness and how can it be evoked and sustained?

Mindfulness

Mindfulness is akin to depth of processing (Craik and Lockhart, 1972), mental capacity usage (Kerr, 1973), and, to some extent also the expenditure of mental effort (Salomon, 1983) that accompanies the "conscious manipulation of the elements of one's environment" (Langer & Imber, 1979). The construct implies the voluntary, controlled employment of non-automatic processing operations. There are numerous content- and task-specific manifestations of mindfulness (or its compliment - mindlessness). It is manifested in attention to details, in the careful examination of a problem's givens, in the consideration of alternatives, in the generation of hypotheses and inferences, in the reading of a text for deeper meanings, in linking new information to remote knowledge structures, in processes of abstraction and decontextualization, and the like (see Langer, in preparation, for a detailed review).

Mindful processing results to some extent from the nature of instructional materials and the activities associated with them. Materials that are more complex, challenging, personally relevant or intrinsically motivating are often treated more mindfully (e.g., Lepper, 1984). However, mindfulness is also a function of other - perceptual, emotional and personological factors. For

example, Zajonc (1980) has observed with respect to emotional factors that "It is ...possible that we can like something or be afraid of it before we know precisely what it is and perhaps even without knowing what it is ...To be sure, the early affective reaction is gross and vague. Nevertheless, it is capable of influencing cognitive processes to a significant degree" (p. 154). The nature of the material encountered may sometimes be a poor determinant of mindfulness considering the possibility that "learning occurs as a result of mental constructions of the learner. These constructions respond to information and stimuli in the environment, but they do not copy or mirror them" (Resnick, 1981, p.660).

The determinants of actual mindfulness can be arranged according to their proximity to the actual manifestation of more or of less mindfulness in a task. Some determinants are more remote and include such factors as overall "need for cognition" - a general tendency to be more or less mindful (Cacioppo, Petty & Morris, 1983), or general personality tendencies. For example, "learned helpless", children tend to expend effort in debilitating self-attributional processes in the face of obstacles; "mastery oriented" children, on the other hand, intensify their efforts in actually overcoming the obstacles (Dweck & Bempenchant, 1980).

Other factors may be closer, or more directly related to the actual mindful engagement at a given moment. For example, individuals with perceived high (though not too high) self

efficacy in performing a task tend to sustain effort expenditure at it when encountering difficulties (Bandura, 1982). The same appears to be the case when individuals perceive a task, topic, activity or medium to be worthy of mental effort expenditure (Salomon, 1984b). Relatedly, overlearning tends to facilitate the person's impression that a newly encountered case resembles familiar ones, hence can be handled the same way without too much attention to detail (Langer, Blank & Chanowitz, 1978). Individuals who are extrinsically motivated or assume a passive learning role behave less mindfully than intrisically motivated ones who assume an active learning role (Benware & Deci, 1984). It can be hypothesized that analoguous to trait and state anxiety, distal factors determine actual mindfulness through the proximal ones, while the latter determine mindfulness more directly.

In sum, mindfulness, an essential ingredient of high road learning, depends to an important extent on a number of factors that need not be related to the actual givens of a particular learning situation. The role of mindfulness in learning from computers is particularly crucial because computers can offer unique learning oppotunities the realization of which greatly depends on learners' self-controlled, volitional engagement.

Mindfulness and Instructional Issues: A case of reciprocal relations

There is ample research that points to the important role played by a priori expectations and perceptions in determining mindfulness in learning from a variety of sources (e.g. Nisbett & Ross, 1980). But this research also shows how a priori perceptions can be overcome by instructions. When students in the Salomon and Leigh study (1984) were told to watch a program not for fun but to prepare for an examination, expenditure of mental effort and inference generation increased (particularly by the more intelligent children); the correlation between ability and performance changed from .09 to .59. With a changed mental set, abilities became mobilized and information processing became more mindful (see also Field and Anderson, 1985). Cambre and Cook (1985) reviewed a number of studies showing that computer anxiety deters computer use and interfers in the process of learning. But contact with computers reduces the initial anxiety, apparently allowing more focussed findfulness in the learning process.

Indeed, mindfulness can be influenced by ongoing, immediate experiences; it is not necessarily a captive of inflexible expectations, proclivities and attitudes. Thus it can be influenced by particular qualities of learning materials (e.g. Mayer, 1976); by team work at the computer where more mindfulness is socially induced (Webb, 1984); by game-like activities designed to be intrinsically motivating (Lepper, 1985); by

inducing an active mental set - "prepare to teach the content to another student" (Benware & Deci, 1984); and by instruction that focuses students' mindfulness on the task (Linn, 1985). But computers can do far more than that to evoke mindfulness; they offer the possibility of partnership in an interaction, paralleled only by personal dialogue with a very intelligent, understanding and patient tutor.

Mindfulness is susceptible to the influence of one's social role, or status in a communicational interaction. Langer and Benevento (1978) have shown that individuals given an "inferior" label during team work came to perform more mindlessly on a task with which they had previous success. The converse was the case when individuals were given a "superior" label - indicating changes in mindfulness as a result of relative status. One becomes more mindful when one feels in charge or when one perceives oneself to actively control the interaction. For, "being in charge" means that alternatives to deal with and results to attain are defined by the individuals, not (as is more often the case in instruction) for them. This, in turn, implies the awareness of alternatives which requires mindfulness in choosing among them, if control of the interaction is to be attained (Langer, 1983).

This is where an important, relatively unique quality of computers - the partner-like relationship with user - can be used to promote mindfulness. Computer's components of information, symbol systems, and activities can afford unique and individually

tailored learning opportunities. But whether these opportunities are taken in actuality greatly depends on learners' a priori choice of mindfulness. Enter the partner-like relations the computer permits, allowing learners to be in (at least) partial control of the process. Such relations can make learners actually engage in the process more mindfully than if they would not have had that control.

However, and despite the invitation for partnership, there appears to be a somewhat paradoxical relationship between students' a priori perceptions and tendencies that determine actual mindfulness in a task and the mindfulness demanded or afforded by interaction with the computer. On the one hand, some students may remain mindless regardless of the partner-like relationship that an interactive program such as Logo enables (Zelman, 1985). This is well in line with the idea that one has to be mindfully inclined to perceive control and experience it (Chanowitz & Langer, 1980). On the other hand, even only expected partner-like relations have been observed to promote mental involvement and learning (Benware & Deci, 1984). This is consistent with the idea that perceived control addresses one's need for self determination and thus promotes deeper involvement in a task (White, 1959).

There is no easy way out of this dilemma. There are some children who, for a variety of reasons, are likely not to become very mindful even in the face of great learning opportunities with the computer. It is likely that for them the low road of

learning, based on game-like and practice-intensive computer activities, is best suited. The intuitive knowledge and improved mastery of tacit skills that may result, are likely to serve as a possible base for later mindful reflection, once metacognitions become applied (see Globerson, this issue). Other children are more sensitive to control opportunities and respond to them with increased mindfulness. For them the high road of learning appears to be more appropriate, promising stronger cognitive effects of computer activity.

Summary

My argument was that all instructional means entail four components - information, symbol systems, afforded activities and relations with learner - that can map upon four corresponding cognitions - knowledge, internal representation, operations and perceptions. They do this by either activating, short circuiting, or modeling these cognitions. The uniqueness of computers lies in the kinds of cognitions they can so affect and in the ways they affect them. Such effects could either be a result of continuous and repeated practice leading to overlearning ("low road learning"), or from mindful, nonautomatic and deliberate processing ("high road learning"). Low road learning is neither practical nor psychologically promising where higher order conceptual learning is expected in a relatively short time.

The extent to which high road learning occurs in actuality, thus leading to lasting and transferable effects, greatly depends

on learners' mindfulness. This mindfulness - the deliberate employment of nonautomatic processes - is partly determined by learners' proclivities, perceptions, expectations, fears, and self-perceptions, and partly by their immediate experiences with the computer. Only when mindfully engaged, can computer's components map upon their corresponding cognitions, leading to their development.

There is a growing body of observations and findings suggesting that the opportunity for such mapping, although available, does not always take place as learners do not become mindful on their own. An important computer quality can help to promote mindfulness in learning - the partner-like relationship which it can establish with the students. This relationship invites mindful control of the process, but this shifts even more responsibility over to learners. It is <u>their</u> choice of how mindfully they are to be while interacting with the computer. One of the important challenges for research is to come up with procedures and unique modes of interaction with the computer that may increase mindfulness.

A final comment. Throughout this paper I have focused on relatively immediate learning effects from computers, as distinguished from those cognitive and societal effects that can be expected over a long period of computer use. Short-term effects, the ones expected over a symester or school year are mainly a matter of high road, mindful learning. It is of course a

somewhat different issue when long-term effects of information technologies are considered, the way Olson (1985) discusses the impact of computers on thought processes as they may evolove over a few decades or even centuries. Such effects, paralleling perhaps those of the print culture, are very likely the result of low road learning and should not be confused with the effects that can be expected and observed on a short term basis. Nor should we conclude from the long-term effects anything pertaining to short-term ones. Print may have indeed freed humans from the constraints of memory, induced and cultivated the ability to distinguish between what has been said and what has been intended, or the ability to be highly explicit and rational. But would anybody expect Yoachim, the child just introduced to print in, say, 1585, to exhibit such effects?

Long-term and short-term effects may look similar, but the mechanisms that lead to each are by necessity quite different. Changes that may take place over a long period of time may not require all that mindfulness; the new technology can be expected to exert its impact in subtle, tacit ways. But the changes that a teacher expects require learners' mindful engagement. The short-term instructional promise of computers does not lie so much with the new technology but with what learners come to do with it during instruction.

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